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Nowell et al.

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(54) **TAPERED VALVE SEAT**

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F16K 1/46	(2006.01)
F16K 1/42	(2006.01)
F16K 25/00	(2006.01)

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CPC ***F04B 53/1087*** (2013.01); ***F04B 53/1032*** (2013.01); ***F16K 1/42*** (2013.01); ***F16K 1/427*** (2013.01); ***F16K 1/465*** (2013.01); ***F16K 15/063*** (2013.01); ***F16K 25/005*** (2013.01)

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CPC F16K 25/005; F16K 1/42; F16K 1/427; F16K 1/465; F16K 15/063; F04B 53/1087; F04B 53/1032; F04B 53/10
USPC 251/332, 333, 359–365, 368
See application file for complete search history.

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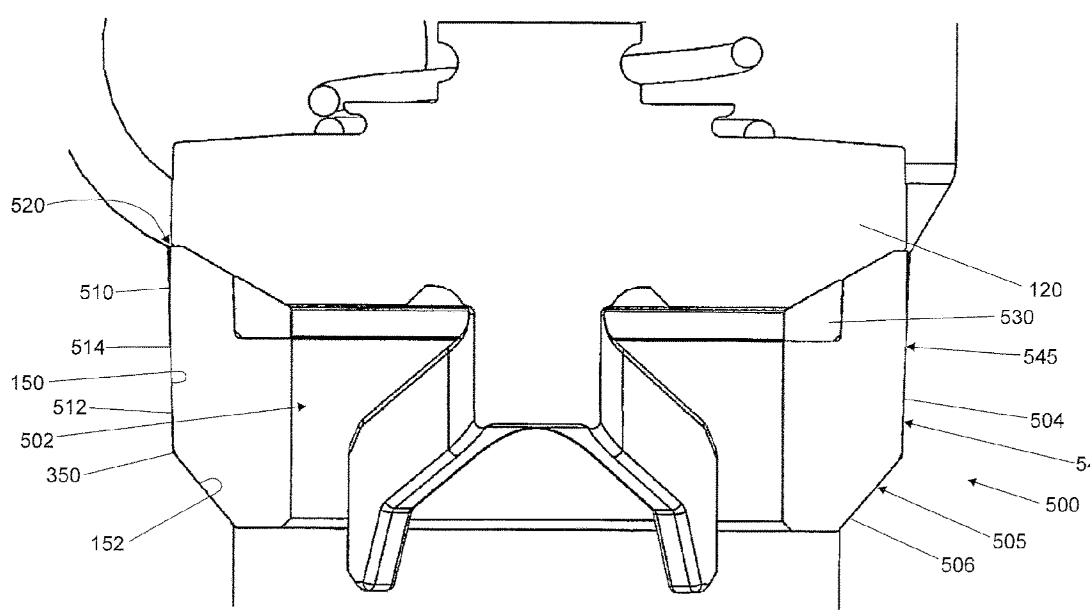
(57) **ABSTRACT**

A valve seat. The valve seat is used in a fluid end of a fracturing pump. The external surface of the valve seat has a tapered portion that retains the valve seat in the fluid end. The external surface also has a portion that is substantially cylindrical. A hardened insert is integrated into a strike face of the valve seat. The tapered portion is at a first end of the valve seat and the tapered portion is at a second end of the valve seat. The second end of the valve seat may be formed such that its exterior surface does not contact the fluid end.

6 Claims, 9 Drawing Sheets



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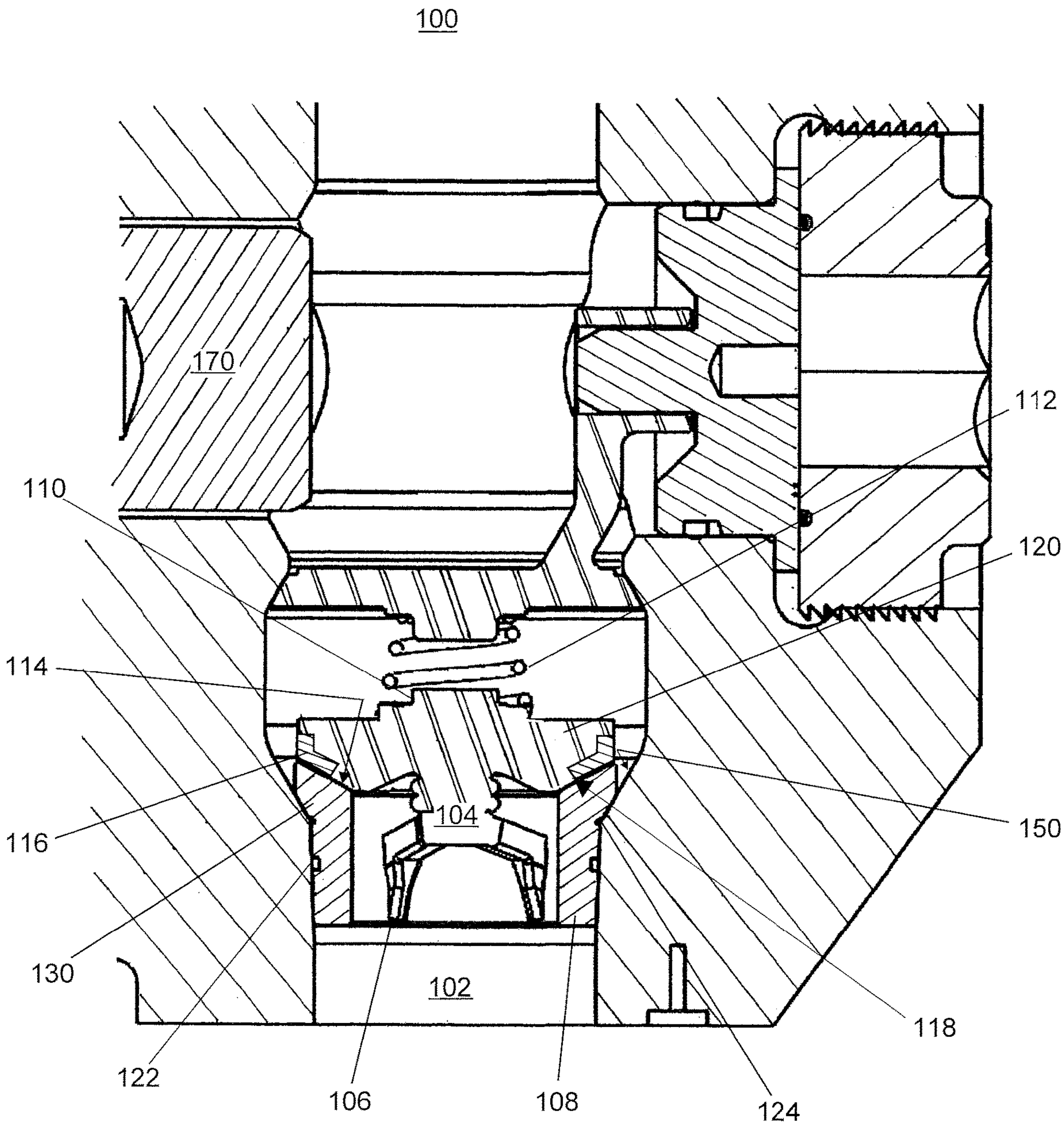

FIG. 1
PRIOR ART

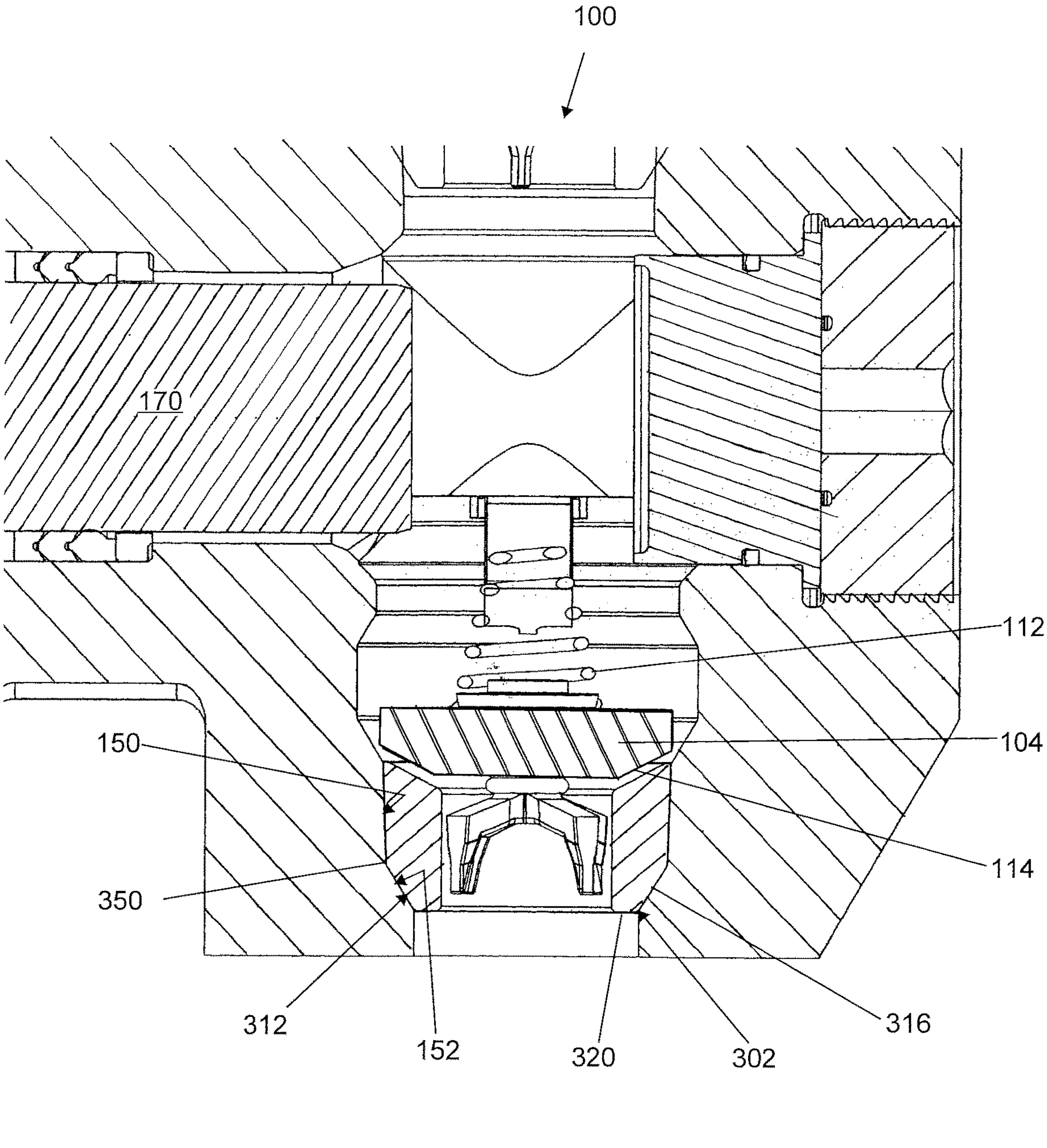

FIG. 2

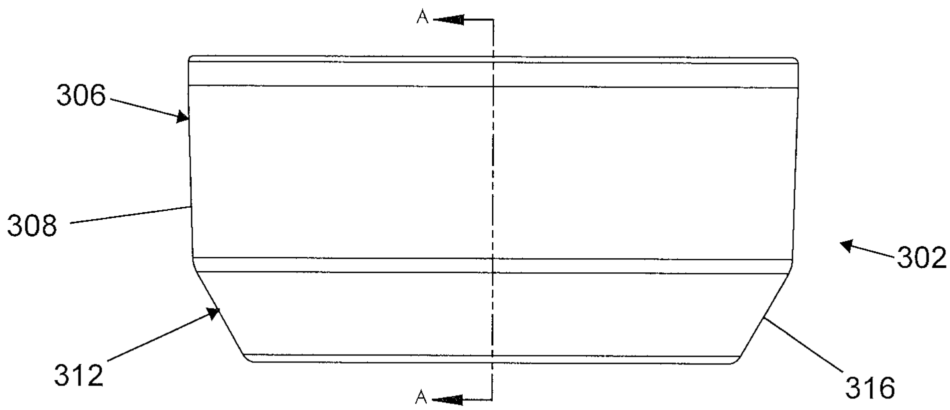
A
306
308
302
312
316
A

FIG. 3A

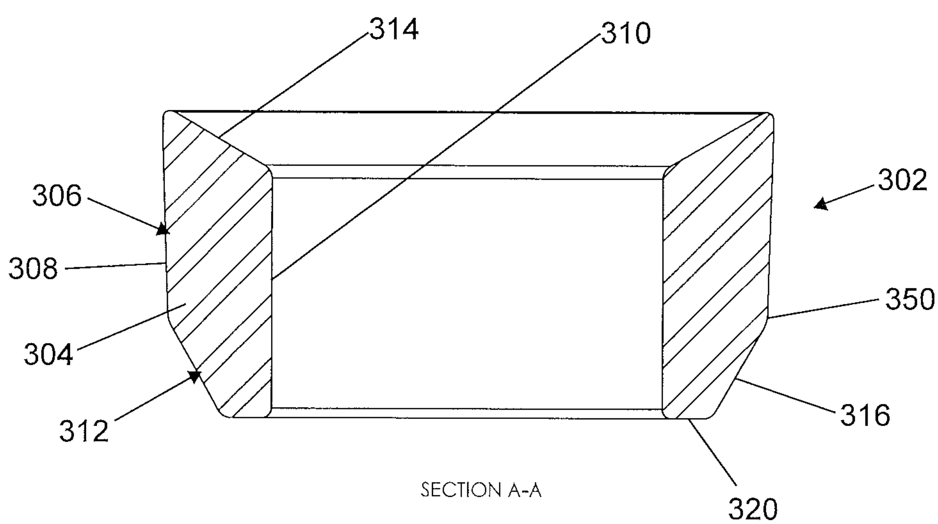
314
310
306
302
308
350
304
312
316
SECTION A-A
320

FIG 3B

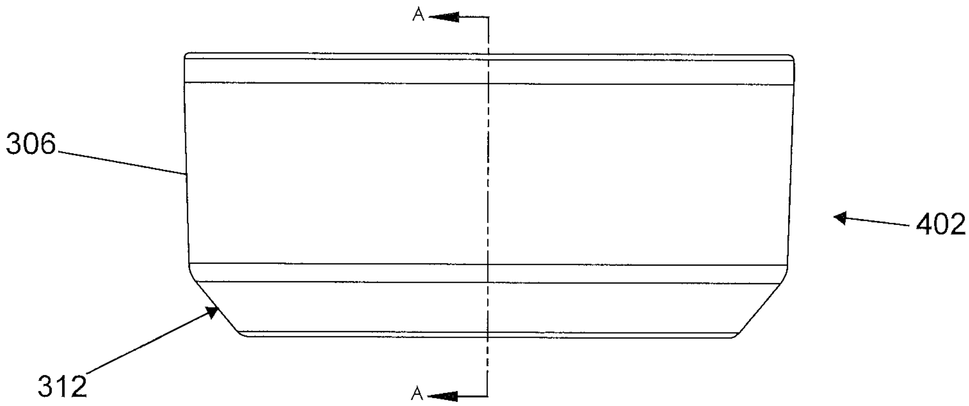

FIG. 4A

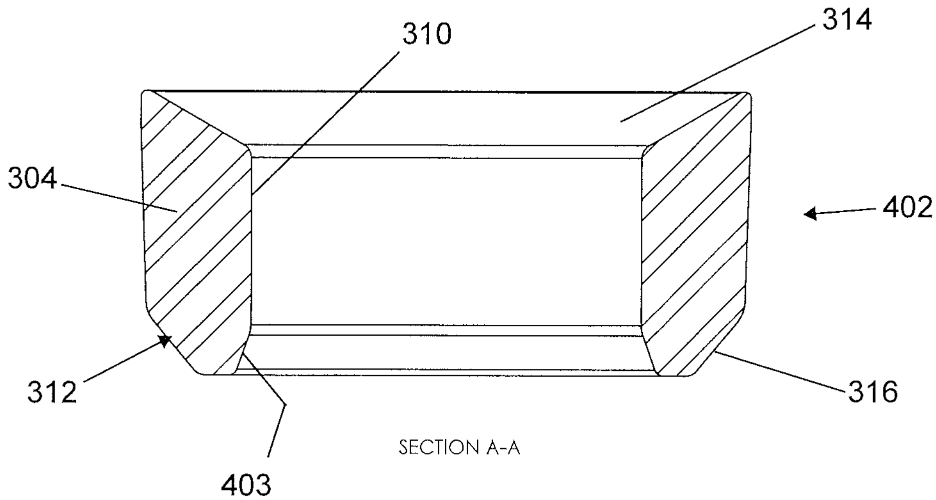

FIG. 4B

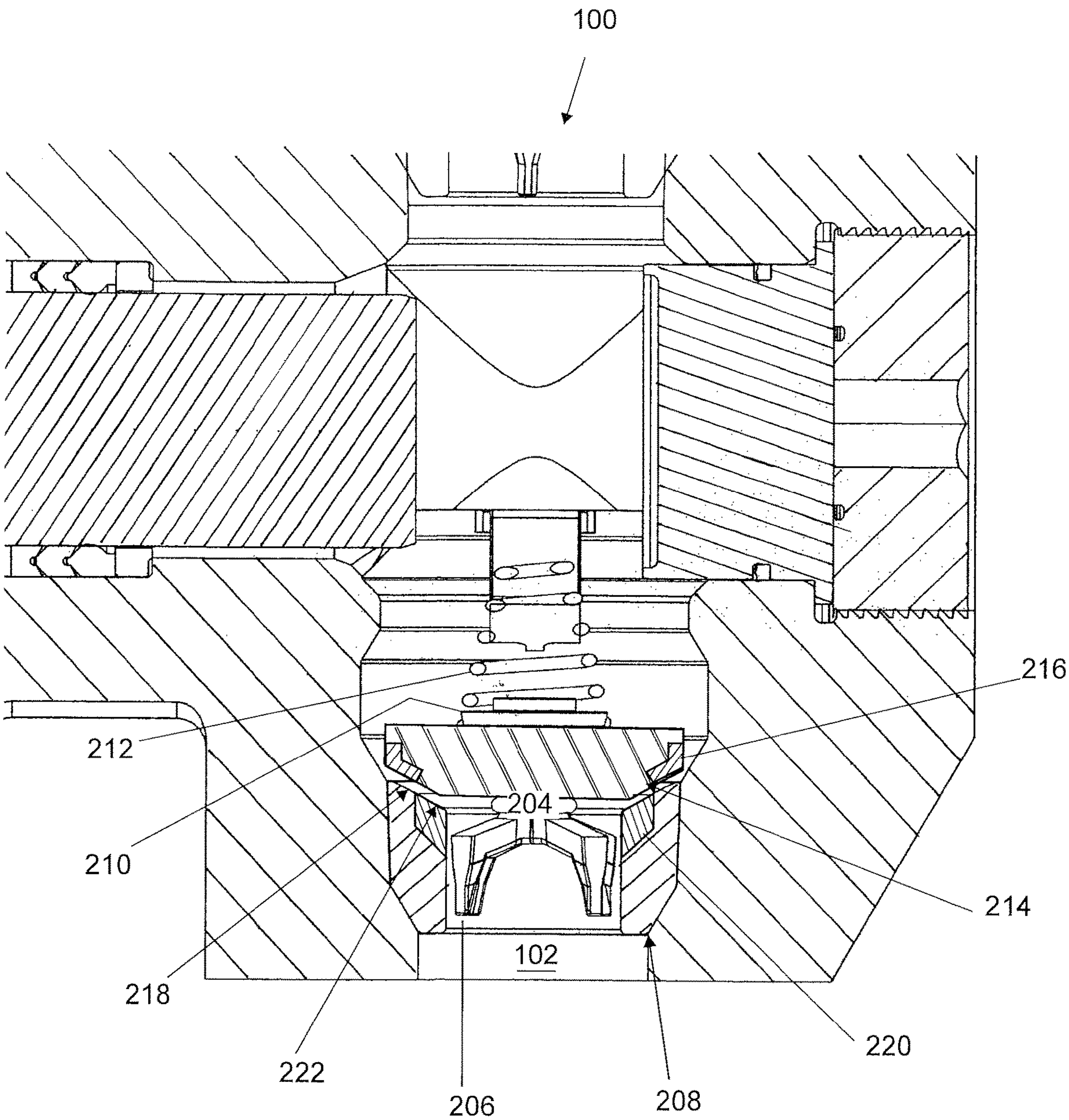

FIG. 5

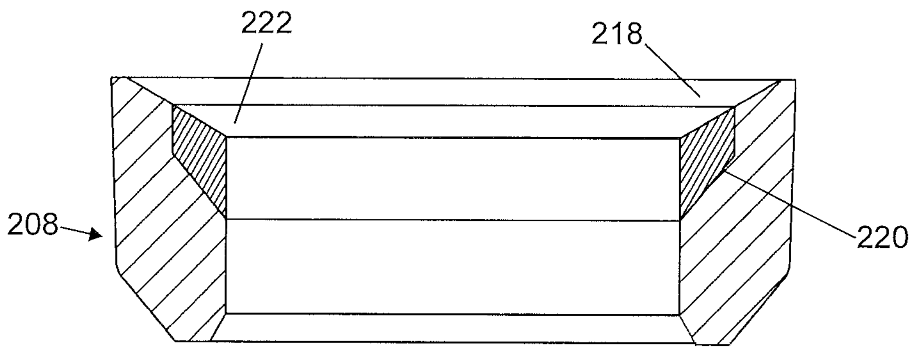

FIG. 6A

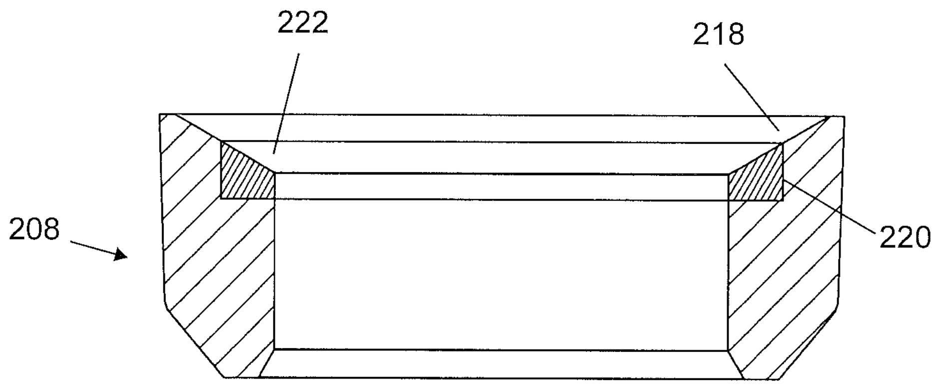

FIG. 6B

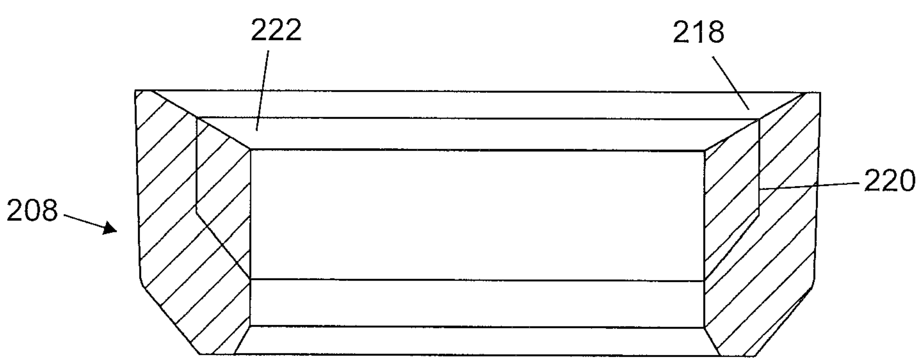

FIG. 6C

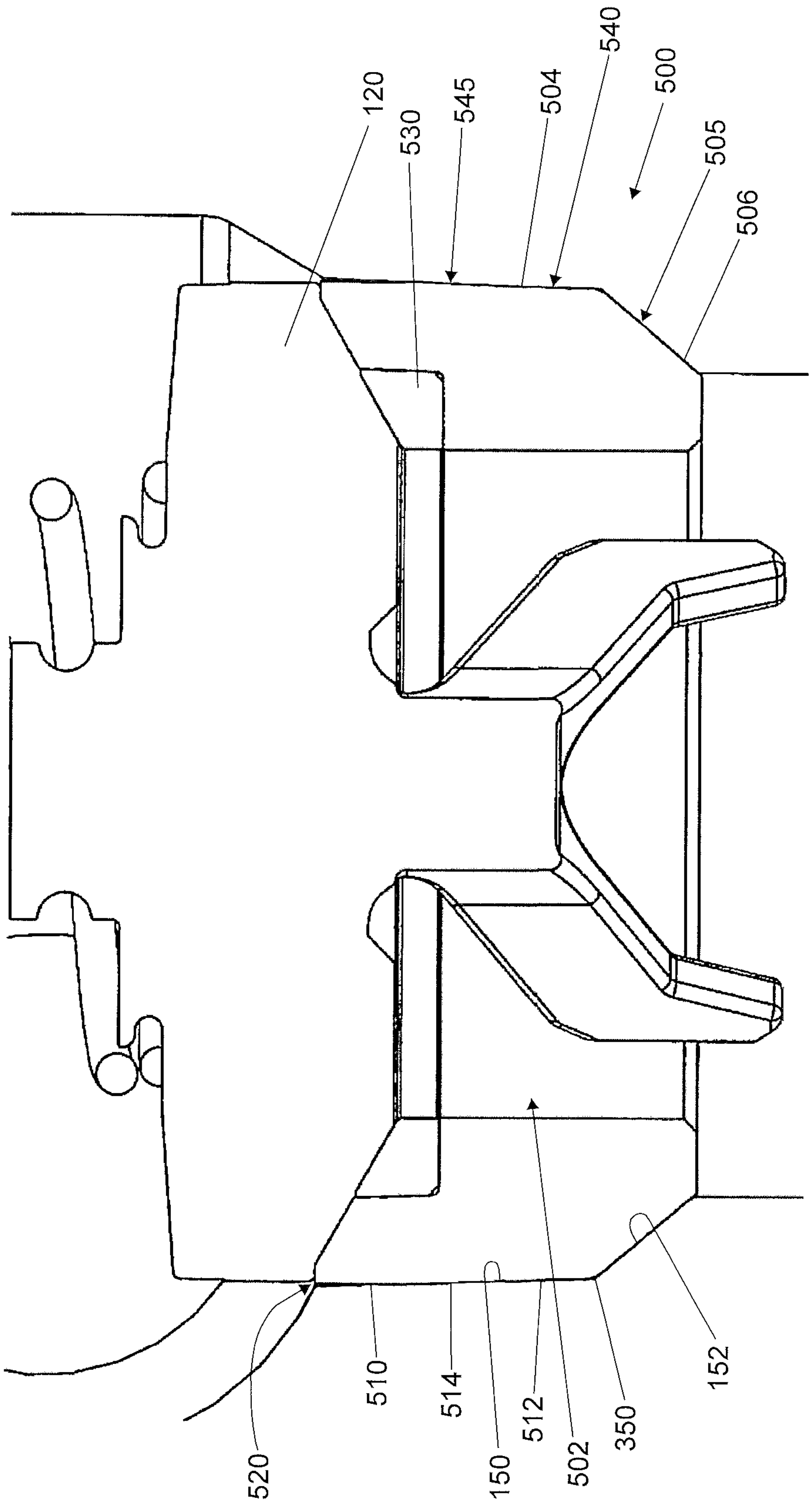

FIG. 7A

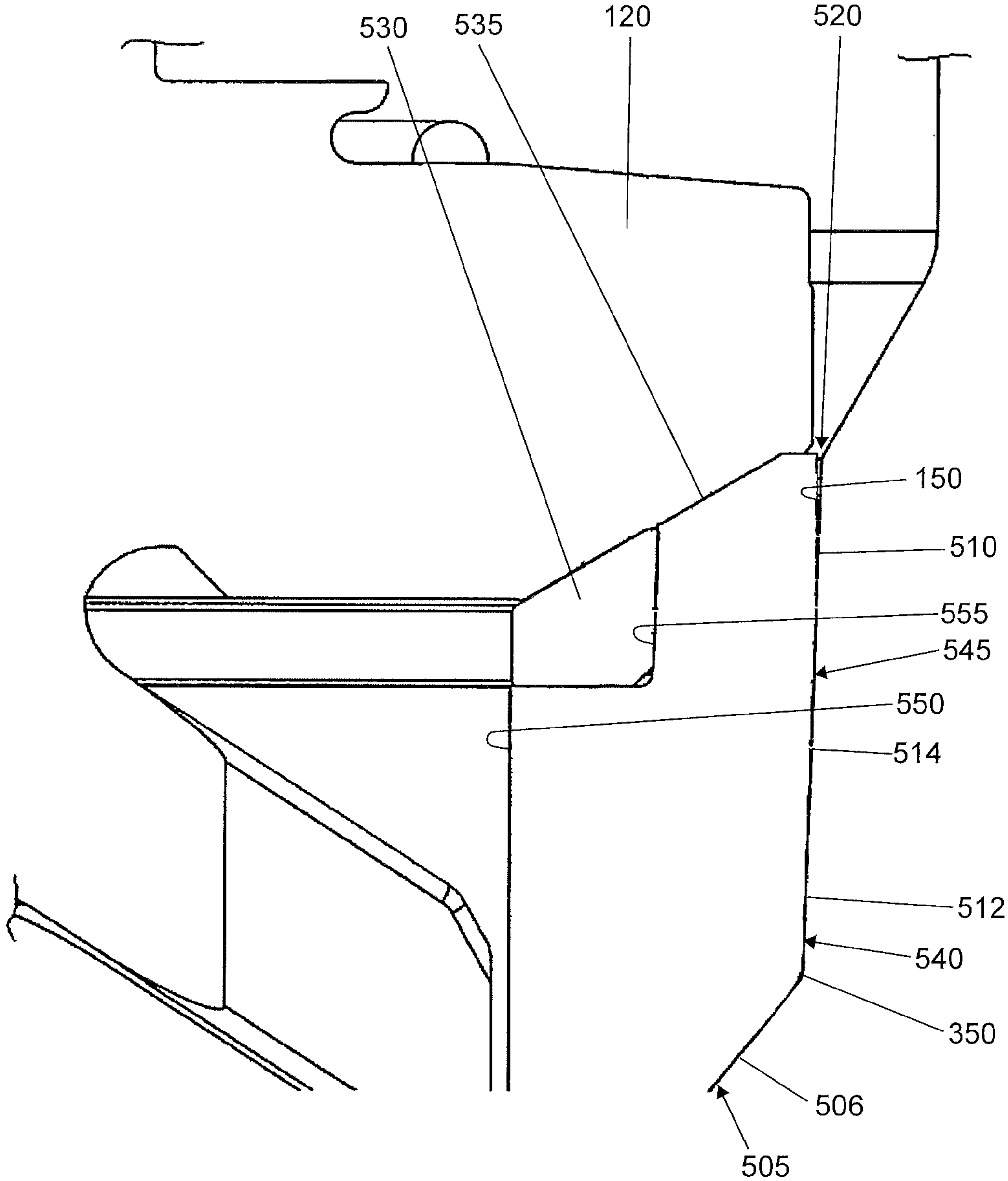

FIG. 7B

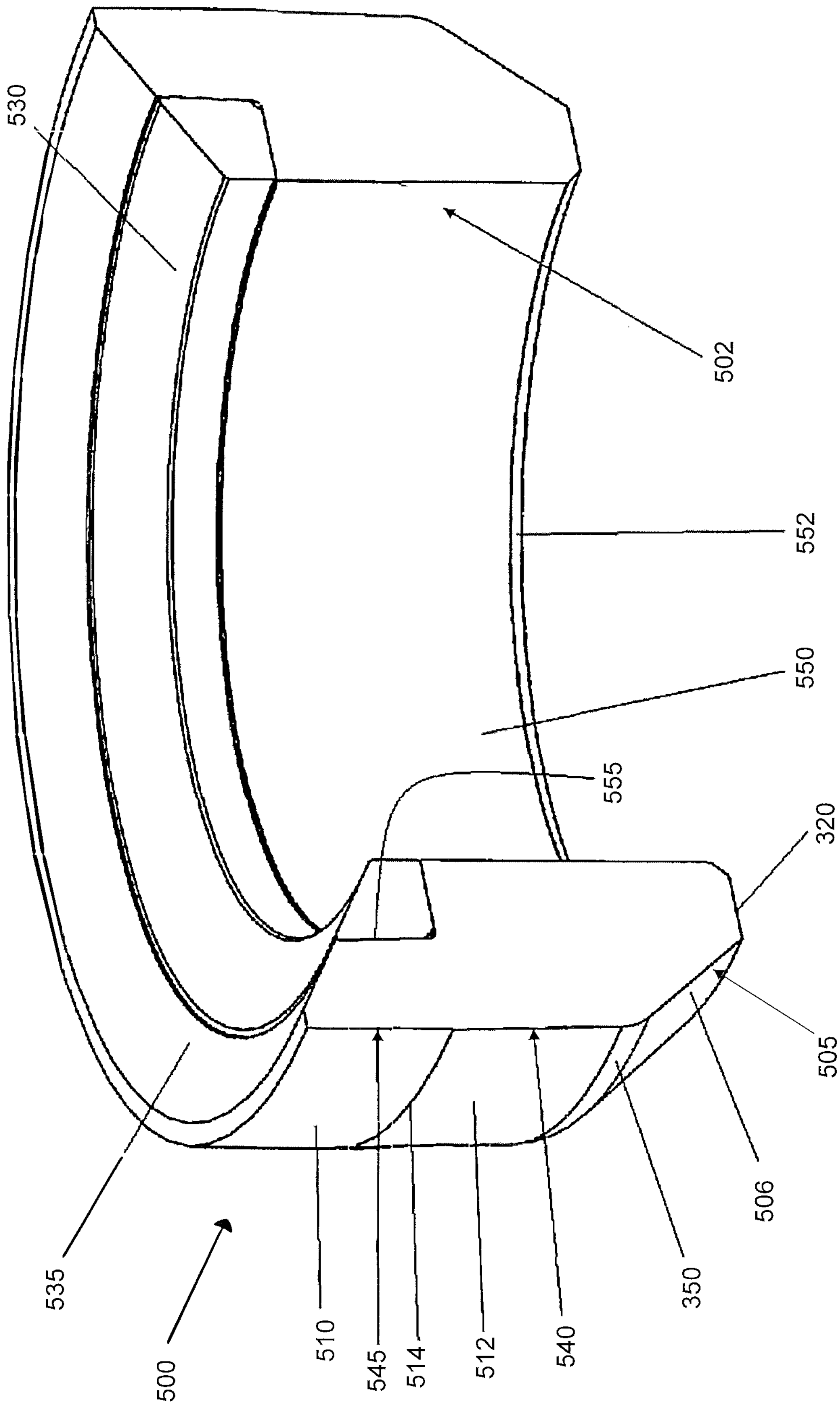

FIG. 8

TAPERED VALVE SEAT

FIELD

This technology relates generally to sealing fluid flow passages inside flow control devices, such as those particularly suited for use in high pressure oil and gas production and processing systems.

SUMMARY

The invention is directed to a valve seat. The valve seat comprises an annular body and an insert. The annular body has a first end and a second end. The first end defines a tapered exterior surface having a frusto-conical first taper conforming to a portion of the pump assembly. The second end defines an internally disposed strike face. The insert is disposed within the second end of the body. The insert is harder than the body and a portion of the insert is integrated with the strike face.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a sectional side view of a fluid end having a prior art valve seat for explanatory purposes

FIG. **2** is a sectional side view of a fluid end having a tapered valve seat.

FIG. **3**A is a side view of the valve seat shown in FIG. **2**.

FIG. **3**B is a sectional view of the valve seat of FIG. **3**A along line A-A.

FIG. **4**A is a side view of an alternative valve seat.

FIG. **4**B is a sectional view of the valve seat of FIG. **4**A along line A-A.

FIG. **5** is a sectional side view of a fluid end having a tapered valve seat containing an insert.

FIG. **6**A is a sectional side view of a valve seat containing an insert.

FIG. **6**B is a sectional side view of a valve seat containing an insert.

FIG. **6**C is a sectional side view of a valve seat containing an insert.

FIG. **7**A is a sectional side view of a fluid end having a tapered valve seat.

FIG. **7**B is a detail view of a gap between the tapered valve seat and valve bore shown in FIG. **7**A.

FIG. **8** is a cutaway perspective view of the valve seat shown in FIGS. **7**A and **7**B.

DETAILED DESCRIPTION

With reference to FIGS. **1**, **2** and **5**, shown therein is a fluid end **100**. A fluid end **100** is the flow control sub-assembly of a high-pressure reciprocating piston pump. Pumps of this type are used in the oil industry to provide high pressure for tasks such as drilling, formation stimulation, also known as fracking, and completed well servicing. They are often referred to as high pressure hydraulic fracturing pumps. The most common design of such a pump includes two sub-assemblies, the power end (not shown) and the fluid end **100**.

The power end converts the rotational input of a drive source to the reciprocating linear motion of pistons **170**, usually with a crankshaft arrangement. The internal components of the power end are enclosed in a relatively clean, lubricated environment and have a much longer service life than the components of the fluid end.

The fluid end **100** controls the flow of the fluid pressurized by the pistons **170**. The pistons **170** are attached to the crank rods of the power end. The sealing integrity of fluid ends must withstand not only high operating fluid pressures, presently 15,000 pounds per square inch and higher, but also must do so while controlling the flow of corrosive and/or abrasive fluids that are notorious for eroding the internal components of typical fluid ends. This abrasiveness and/or corrosiveness, combined with high flow rates used in standard service, dramatically shorten the life of typical fluid ends when compared to that of typical power ends.

Fluid ends **100** typically have from two to five or more identical sections consisting of components that accomplish the purpose described above. Each fluid end comprises valves **104**. The valves **104** control the inlet of low pressure fluid and outlet of high pressure fluid from each fluid end **100** section.

The valves **104** are typically identical and are an assembly that has a body **120**, a return mechanism, such as a spring **112**, and a sealing face **114** formed on the body. The valves **104** are positioned within the inlet and outlet sections to control fluid flow in and out of the fluid end **100**. As shown in FIGS. **1**, **2** and **5**, the valve **104** is in an inlet section **102** of the fluid end **100**.

Each sealing face **114** seals against a valve seat. A valve seat is typically a tube that has been hardened, or is made of harder material than the fluid end, that is to installed in the inlet and outlet sections of the fluid end. The valve seat and provides a hardened sealing surface for the sealing face **114** of the valve **104** to seal against. Without the hardened sealing surface of the valve seat the area would quickly erode reducing the service life of the fluid end.

Recent developments in the energy exploration industry require an increased maximum sustained pressure in pumps from around 8,000 psi to 15,000 psi or more with expected maximum spikes up to 22,500 psi. This increase in maximum pressure causes failures in components not seen at lower pressures. Typical failures now include the failure of valves due to erosion of the valve sealing face **114** and seat sealing face **118** which is accelerated by the large closing forces of the valve sealing face against the valve seat sealing face. When either sealing face fails leakage occurs around the component. Leakage reduces the maximum pressure and flow capabilities of the system. Leakage of an abrasive fluid at such high pressures quickly erodes the area requiring repair or replacement of the entire fluid end. A fractured fluid end body is always a catastrophic failure requiring replacement.

Efforts to eliminate the erosion of the valve sealing face have included hardening both sealing faces. The mating hardened surfaces provide an improved seal and allow the system to operate as desired. However, the impact of the hardened valve sealing face against the valve seat sealing face increases the erosion rate of both surfaces due to the closing force imparted to the valve by the valve return spring and the internal pressures of the fluid end. This failure occurs in an unacceptably short time requiring repair or replacement of the valve and/or the valve seat Improvements are needed in the internal sealing of fluid ends to increase operating life while reducing downtime and operating cost.

With reference to FIG. **1**, fluid end **100** comprises a prior art valve seat **108**. The inlet passage, or port **102** is shown with the valve **104** in the closed position. The valve **104** body **120** has an alignment structure **106** and a protrusion no. The alignment structure **106** assists in maintaining proper valve **104** orientation to a valve seat **108** when in operation. Protrusion **110** centers a coil spring **112** that is typically used to apply a closing force to the valve **104** during operation. When the valve **104** is closed by the coil spring **112**, the valve sealing face **114** contacts the valve seat **108**.

The valve seat **108** is installed in the inlet port **102**. Typically, the valve seat **108** is precisely machined to fit in the fluid end **100**. This fit may be close enough to prevent the gap between the seat **108** and fluid end **100** from leaking. It is typical to have a seal located in a seal groove **122** on the outside diameter of the seat **108** to keep the joint from leaking. The valve seat **108** is installed by inserting it into an appropriately sized fluid passage bore **150** in the inlet port **102** of the fluid end **100**. The valve seat **108** has a tapered flange **130**. The valve seat flange **130** bottoms out on the valve seat bore **150**.

The seat **108** defines a sealing surface **118** that is complementary to the sealing surface **114** of the body **120**. The valve sealing surface **114** contacts the seat sealing surface **218** stopping fluid flow.

The valve seat flange **130** resists the tendency of the valve seat HA to be driven deeper into the inlet port **102** by the forces produced by the fluid end. These flanges **230** typically form the upper portion of a valve seat **108**. As shown, the flange **130** meets the remainder of the valve seat **108** at a transition point **124**. The transition point **124** may be the apex of a ninety degree to one hundred eighty degree external angle on the outer surface of the valve seat **108**. In all such valve seats **108**, the transition point has an external angle of less than one hundred eighty degrees.

There is a stress concentration at the transition point **124** which is a typical failure point. Attempts to reduce the stress concentration by adding a stress relief groove have been unsuccessful. A sharp transition at the flange additionally produces a stress concentration in the fluid end **100** body and increases the likelihood of cracking the internal wall of the fluid end **100** body in that area. Typically, the wall thickness of the fluid end **100** body has been increased in this area to reduce these failures however size and cost restraints prevent adequate increases in the wall thickness.

The sealing surface **114** may be hardened by a post manufacturing process, such as nitriding or flame hardening, or is manufactured from a hard material such as carbide. It is advantageous to have the hardened valve sealing surface **114** to minimize erosion. Seat **108** may also have the seat sealing surface **118** hardened by a post manufacturing process like those performed on the valve sealing surface **114**. However, the press fit or close fit method of installation combined with the residual stresses from the post manufacturing process make it extremely difficult to install the seat **108** without breaking it. Because of these installation difficulties, seat **108** is typically made entirely of carbide or some other hard material thus reducing, but not eliminating, installation difficulties.

A valve insert **116** may be placed in the body **120** at the sealing surface **114**, and may be either permanently attached or replaceable. The valve insert **116** can be made of any of a number of elastomeric materials. The purpose of valve insert **116** is to provide more sealing capability for the valve **104**. While the primary sealing is accomplished by the metal to metal contact of the valve sealing surface **114** to the seat sealing surface **118**, it is advantageous to have the elastomeric material encapsulate and seal around any solids trapped between the valve insert **116** and the seat sealing surface **118**.

During operation the valve **104** reciprocates axially between open and closed positions. In the open position fluid flow occurs and in the closed position fluid flow is blocked.

As the valve **104** moves from the open position to the closed position the valve insert **116** contacts the seat sealing surface **118** first and deforms around any trapped solids. Once the valve insert **116** deforms, or compresses, axially the valve sealing surface **114** contacts the seat sealing surface **118** and stops moving. Erosion occurs with each cycle in large part due to the impact of the valve sealing surface **114** on the seat sealing surface **118**.

The repeated impacts of both sealing surfaces **114**, **118** erode only in the area that the two surfaces **114**, **118** contact each other and are typically the point of failure. Repair of the fluid end **100** requires the replacement of both the valve **104** and the seat **108**. The replacement cost of a carbide seat **108** is very expensive and the industry can benefit from an improvement that reduces this cost.

With reference to FIG. **2**-**4**B, the fluid end **100** contains an improved valve seat **302**. The valve seat **302** has no flange **130** (FIG. **1**). Rather, as best shown in FIGS. **3**A and **3**B, the valve seat has a body **304** with an annular ring portion **306** and a tapered lower portion **312**. The annular ring portion **306** has an outer surface **308** that is substantially cylindrical and an inner surface **310** that is substantially complementary to a cylinder. A slight taper may be used on the outer surface **308** of the annular ring portion **306**.

A seat sealing surface **314** is disposed at a first extremity of the annular ring portion. The sealing surface **314** is complementary to the valve sealing surface **114** of the valve **104** body **120**.

The tapered lower portion **312** generally is defined by a continuation of the inner surface **310**, but having a tapered outer surface **316**. The internal bore **150** has an internal taper **152** that corresponds to the tapered portion **312** of the valve seat **302** body **304**. The tapered outer surface **316** and outer surface **308** meet at a transition point **350**. The transition point **350** has an external angle of greater than one hundred eighty degrees. Thus, the transition point **350** has reduced stress as compared to that of the prior art.

The tapered portion **312** terminates at a bottom surface **320** of the valve seat **302**. As shown, the bottom surface **320** does not contact the internal bore **150** of the fluid end **100**. Thus, the force applied through the valve seat **302** to the fluid end **100** body is provided at the internal taper **152** of the internal bore **150**. The geometry of valve seat **302** eliminates any transition that would provide a stress concentration point thus increasing the service life of the valve seat **302**. Stress applied through the valve seat **302** is evenly distributed on internal taper **152** and tapered outer surface **316**, rather than being concentrated at a transition.

FIGS. **4**A and **4**B show an alternative valve seat **402**. The valve seat **402** is largely identical to seat **302**, but the tapered portion **312** has a tapered inside diameter **403**. The tapered inside diameter **403** tends to reduce turbulent flow within the valve seat **402**, reducing erosion on the inner surface **310** of the seat **402**.

With reference to FIG. **5**, an alternative valve **204** and valve seat **208** are shown in a inlet port **102** of the fluid end **100**. The valve seat **208** has generally the same geometry as valve seats **302**, **402**. However, valve seat **208** comprises an insert **220** disposed in the seat sealing surface **218**.

The valve **204** comprises a valve sealing surface **214**. The valve sealing surface **214** may be hardened by a post manufacturing process, such as nitriding or flame hardening, or may alternatively be manufactured from a hard material such as carbide. It is advantageous to have the hardened valve sealing surface **214** to minimize erosion. The area of the valve sealing surface **214** is larger than that of typical valves, such as the previously attempted solution described above. The larger surface **214** distributes the impact force about a greater area, reducing the impact force at any particular point on the two sealing surfaces **214**, **218**. Distributing the closing force reduces the amount of erosion caused by the impact force.

A valve insert **216**, made of a deformable elastomeric material, may be formed on a portion of the valve sealing surface **214**. Valve insert **216** may be similarly formed to insert **116** in FIG. **1**, or other known inserts such as that of U.S. Pat. No. 9,435,454, issued to Blume, the contents of which are incorporated herein by reference.

In one embodiment, the valve seat **208** is made of stainless steel or other corrosion resistant material. Typically, however, such material is not hard enough to adequately protect against erosion. Therefore, the seat insert **220** is made of a hardened material, such as tungsten carbide, to resist erosion at the location of repeated contact with the valve sealing surface **214**. Seat insert **220** is installed in seat **208** and retained by interference fit, a taper lock design or the like. The insert **220** defines a seat insert sealing surface **222** that is complementary to the valve sealing surface **214**.

During operation the valve **204** reciprocates axially between open and closed positions. In the open position fluid flow occurs and in the closed position fluid flow is blocked. As the valve **204** moves from the open position to the closed position the valve insert **216** contacts the seat sealing surface **218** first and deforms around any trapped solids. Once the valve insert **216** deforms, or compresses, axially the valve sealing surface **214** contacts the seat insert sealing surface **222** and stops moving.

As shown in FIGS. **6**A-**6**C, the seat insert **220** may be characterized by different shapes. The seat insert **220**, at the top cylindrical portion, has a larger outer diameter. The sum of the seat insert sealing surface **222** and the seat sealing surface **218**, has a larger surface area than conventional valve seats. As discussed with respect to valve sealing surface **214** area, the larger area allows for less force per unit area between the sealing surfaces **214**, **218**, **222** without reducing the closing force. An additional advantage of the increased outer diameter is that the seat insert **220** may now be installed without decreasing the seat **208** wall thickness to a point where premature failure of the seat **208** will occur.

Additional embodiments are shown in FIGS. **6**B and **6**C. These embodiments illustrate variations in the installation and retention methods of the seat insert **220** in the seat **208**.

While three of the preferred embodiments have been described in detail there are numerous other ways to accomplish this improvement that are also contemplated. Any seat **208** having a separate component that is harder than the base material of the seat and is approximately complementary to the valve sealing surface **218** is contemplated by this improvement. For instance, the seat insert **220** could be the outer diameter of the seat **208** and the inner diameter used to attach the seat insert to the seat by threading, interference fit or the like. This would require the valve sealing surface to also be the outer diameter portion of the valve and the valve insert to be the inner portion of the valve.

As shown in FIGS. **7**A and **7**B, a valve seat **500** has an outer surface **504** that may not match the bore **150** of the fluid end **100** precisely. In this embodiment, a valve seat **500** has an annular ring portion **502** with an outer surface **504** and a tapered portion **505** with a tapered portion outer surface **506**. The outer surface **504** of the valve seat **500** differs from that of FIG. **2** and FIG. **5**, as the angle of the outer surface relative to the internal bore **150** changes more than once along its length. Further, the outer surface **504** only partially conforms to the internal bore **150**.

In one embodiment, a first outer surface section **510** and a second outer surface section **512** meet at an angle at transition **514**. Transition **514** is generally disposed on a curve around the external surface **504** of the seat **500**. It should be understood that the valve seat **500** generally conforms to the bore **150** at the second outer surface section **512** and abuts the bore when seated. In one embodiment, the second outer surface section may be press fit against the bore **150**.

As shown best in FIG. **7**B, the change in the taper of outer surface **504** at the transition **514** causes the fully seated valve seat **500** to define a gap **520** between the first outer surface section **510** and the bore **150**. In one embodiment, the first outer surface section **510** may be offset from the bore **150** by less than 5 degrees. This angle may be less than one degree. It should be understood that the external angle between the first outer surface section **510** and the second outer surface section **512** at the transition **514** is just greater than one hundred eighty degrees. In one embodiment, the external angle at transition **514** is between one hundred eighty and one hundred ninety degrees.

The second outer surface section **512** and the tapered portion outer surface **506** both fully seat against the bore **150**. However, gap **520** reduces the tendency of the valve seat **500** to become lodged within the fluid end **100** after repeated impacts between the valve seat **500** and the valve body **120**. Therefore, the small gap **520** dramatically improves the ease of removal and replacement of the valve seat **500**.

Thus, in the embodiment of FIG. **8**, the valve seat **500** comprises a tapered portion **505**, an intermediate portion **540**, and a strike face portion **545**, each defined by the shape of its outer surface. Generally, a transition point **350** defines the boundary between the tapered portion **505** and intermediate portion **540**, while the transition **514** defines the boundary between the intermediate portion **540** and strike face portion **545**.

First, the tapered portion **505** is defined by the tapered portion outer surface **506** and an inner surface **550**. The inner surface **550** may comprise a surface complementary to the outer surface of a cylinder, or may have an inverse tapered portion or bevel **552** as shown. The inner surface **550** and tapered portion outer surface **506** terminate at the flat bottom surface **320**. In the embodiment of the valve seat **500** shown in FIG. **7**A, the entire tapered portion outer surface **506** engages the bore **150**. None of the bottom surface **320** seats on the bore **150**.

Second, the intermediate portion **540** is defined by the inner surface **550** and the second outer surface section **512**. The intermediate portion should be of substantially constant thickness, outer diameter, and inner diameter; though a minor taper from the transition **514** to the transition **350** may exist. The taper of the intermediate portion **540** is significantly less per unit length than the taper of the tapered portion **505**.

Third, the strike face portion **545** is defined by the inner surface **550**, including a portion of the insert **530** that conforms to the inner surface, and the first outer surface section **510**. The strike face portion **545** has a strike face **535** which conforms to a surface of the valve body **120**. A recess **555** conforms to the insert **530** for seating the same. The portion of the insert **530** forms a part of the strike face **535**.

The strike face **535** and inner surface **550** both include, in part, the insert **530**. The insert **530** conforms to adjacent surfaces along the strike face **535** and inner surface **550**. In the embodiment of FIG. **8**, the insert **530** is only disposed in the strike face portion **545**. In the embodiment of FIG. **8**, the first outer surface section **510** is substantially cylindrical in shape while the adjacent bore **150** has a slight taper (roughly matching second outer surface section **512**). Therefore, the strike face section **545** does not contact the bore **150**, forming gap **520** (FIG. **7**B).

Modifications to this geometry could be made, for example, if the bore **150** abutting the annular ring section **502** is complementary to a cylinder, the first outer surface section **510** could taper slightly inward to generate gap **520**.

The strike face portion **545** does not engage the bore **150** at any point. Thus, all bore engagement between the valve seat **500** and bore **150** takes place at the tapered portion **505** and intermediate portion **540**.

As shown best in FIG. **8**, the entire valve seat **500**, inclusive of the insert **530**, is ring-shaped, and is defined by a cross-section that has no concave angles. Eliminating concave angles enhances the strength of the valve seat and prevents failure at weak points, such as the weak point at transition **130** (FIG. **1**).

The various features and alternative details of construction of the apparatuses described herein for the practice of the present technology will readily occur to the skilled artisan in view of the foregoing discussion, and it is to be understood that even though numerous characteristics and advantages of various embodiments of the present technology have been set forth in the foregoing description, together with details of the structure and function of various embodiments of the technology, this detailed description is illustrative only, and changes may be made in detail, especially in matters of structure and arrangements of parts within the principles of the present technology to the full extent indicated by the broad general meaning of the terms in which the appended claims are expressed.

The invention claimed is:

1. A valve seat configured to be disposed within a pump assembly, the valve seat comprising:

an annular body having a first end, a second end, and an intermediate portion disposed between the first end and the second end, in which:

the first end defines a tapered exterior surface having a frusto-conical first taper conforming to a portion of the pump assembly;

the second end defines an internally disposed strike face and a cylindrical exterior surface; and

the intermediate portion is characterized by an exterior surface situated at a convex angle relative to the cylindrical exterior surface of the second end and situated at a convex angle relative to the tapered exterior surface of the first end; and

an insert disposed within the second end of the body, in which the insert is harder than the body and in which a portion of the insert is integrated with the strike face.

2. A valve seat configured to be disposed within a pump assembly, the valve seat comprising:

an annular body having a first end, a second end, and an intermediate portion disposed between the first end and the second end, in which:

the first end defines a tapered exterior surface having a frusto-conical first taper conforming to a portion of the pump assembly; and

the second end defines an internally disposed strike face and a first exterior surface; and

the intermediate portion is characterized by a second exterior surface;

in which the first exterior surface and the second exterior surface intersect and form a first angle; and

in which the second exterior surface and the tapered exterior surface intersect and form a second angle; and

in which the second exterior surface has a second taper from the first angle to the second angle;

an insert disposed within the second end of the body, in which the insert is harder than the body and in which a portion of the insert is integrated with the strike face.

3. The valve seat of claim **2** in which the taper of the second taper is less than the taper of the first taper.

4. A fracturing pump having a fluid passage bore with an internal taper comprising:

a valve body having a sealing surface; and

the valve seat of claim **2**;

in which the sealing surface and the strike face are complementary in shape; and

in which the internal taper of the fluid passage bore is seated against the tapered exterior surface of the first end of the valve seat; and

in which the first exterior surface does not contact the fluid passage bore.

5. The fracturing pump of claim **4**, in which the insert is disposed entirely between a vertex of the first angle and the second end.

6. The fracturing pump of claim **4**, in which the second exterior surface is seated against the fluid passage bore.

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